



Original Article

# Effects of concentric and eccentric control exercise on gross motor function and balance ability of paretic leg in children with spastic hemiplegia

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**Abstract.** [Purpose] This study examines the effect of concentric and eccentric control training of the paretic leg on balance and gross motor function in children with spastic hemiplegia. [Subjects and Methods] Thirty children with spastic hemiplegia were randomly divided into experimental and control groups. In the experimental group, 20 min of neurodevelopmental therapy and 20 min of concentric and eccentric control exercise were applied to the paretic leg. In the control group, 40 min of neurodevelopmental therapy was applied. The Pediatric Balance Scale test and standing and gait items of the Gross Motor Function Measure were evaluated before and after intervention. [Results] In the experimental group, Gross Motor Function Measure and Pediatric Balance Scale scores statistically significantly increased after the intervention. The control group showed no statistically significant difference in either score after the intervention. [Conclusion] Concentric and eccentric control exercise therapy in children with spastic hemiplegia can be effective in improving gross motor function and balance ability, and can be used to solve functional problems in a paretic leg.

**Key words:** Cerebral palsy, Gross motor function, Strength training

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## INTRODUCTION

Children with spastic hemiplegia experience decreased balance ability and abnormal gait because of decreased weight-bearing in the paretic leg<sup>1-3)</sup>. Diminished motor ability in the paretic leg causes weakening of the quadriceps, ankle plantar flexors, and ankle dorsiflexors<sup>4,5)</sup>. To enhance balance and motor ability in the paretic leg in children with spastic hemiplegia, a therapeutic approach promoting weight-shifting to the paretic side and strengthening of paretic leg muscles is required<sup>4,6)</sup>.

Muscle-strength-enhancement exercise in children with cerebral palsy results in an increase in stride length and gait velocity, decreased crutch gait, and improvement in the Gross Motor Function Measure<sup>7)</sup>. Brown et al.<sup>8)</sup> reported that muscle strength of the ankle plantar flexors and dorsiflexors of the paretic leg in children with spastic hemiplegia was respectively 75% and 72% of that of the unaffected side. Horvat<sup>9)</sup> reported that muscle strength of knee extensors and flexors in the paretic leg in cases of spastic hemiplegia was respectively 42% and 52% of that of the unaffected side. Horvat<sup>9)</sup> applied a gradual resistance exercise program in children with spastic hemiplegia for 8 weeks and reported that knee flexor and extensor muscle strength increased 100% and 129%, respectively. This suggests that knee-muscle-strength exercise is necessary to improve walking function in children with spastic hemiplegia; the benefits include gross motor function enhancement, faster walking,

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and increased energy efficiency after knee extensor training<sup>10</sup>). Hwang<sup>11</sup>) implemented eccentric muscle strength exercise for the paretic leg in patients with hemiplegia and reported improvement of muscle strength, cadence, gait velocity, and weight-bearing on the paretic side during walking.

Research on the positive impact of eccentric muscle strength exercise on daily life is ongoing. However, most studies involved muscle strength exercise in supine, prone, and sitting positions. Few studies have evaluated the impact of weight-bearing muscle-strength-enhancement training of an independent and controlled paretic ankle and knee on balance ability and gross motor function. Hence, this study examined the effects of weight-shifting to a standing paretic leg and concentric and eccentric muscle strength exercise on balance and gross motor function in children with spastic hemiplegia.

## SUBJECTS AND METHODS

Thirty children with spastic hemiplegia were randomly divided into experimental and control groups. The inclusion criteria were as follows: diagnosis of spastic hemiplegia, Gross Motor Function Classification System (GMFCS) level I–II and able to walk and jump<sup>12</sup>), modified mini-mental state examination score over 25<sup>13</sup>), absence of vision or hearing deficits, and no medicine or surgery that affects balance. All protocols were approved by the University of Daejeon. Before participation, the procedures, risks, and benefits were explained to the participants, who gave informed consent. Participant rights were protected according to the guidelines of the University of Daejeon.

The Pediatric Balance Scale (PBS) and Gross Motor Function Measure (GMFM) were used in the study. The PBS can be applied in children with brain damage and consists of a total of 14 items in 3 domains, including sitting, standing, and changing of position. The highest score is 56 and a higher score indicates better standing balance ability<sup>14</sup>). The GMFM measures the change in motor function in children<sup>15, 16</sup>). The participants performed 88 kinds of motions in 5 domains without assistance by the tester. Among the 5 domains, total scores in domain D (standing) and domain E (gait, running, and jumping) were compared in this study.

The duration of training was 4 weeks. In the experimental group, 20 min of neurodevelopmental therapy and 20 min of muscle-strength-enhancement training were applied to the paretic leg. In the control group, 40 min of neurodevelopmental therapy was applied. The method of concentric and eccentric muscle-strength-enhancement training for the paretic leg is as follows. A subject stands on a height-adjustable table where he/she is able to bear weight on the paretic leg while holding a stall bar with the upper limb on the paretic side. The subject pushes a ball back and forth on the ground using the non-paretic leg by controlling the ankle and knee joints of the paretic leg. The motion is repeated 10 times for one set followed by 1 min of rest. A total of 10 sets are performed.

General characteristics of the research subjects were examined by cross-tabulation analysis and independent t-tests using descriptive statistics. A paired t-test was used to compare differences before and after the experiment in each group. An independent t-test was used to compare differences before and after the experiment between the 2 groups. The Statistical Package for the Social Sciences for Windows, version 18.0 (SPSS, Chicago, IL, USA) was used for statistical analysis. A statistical significance level was set at  $\alpha=0.05$  for all data (Table 1).

## RESULTS

In the experimental group, PBS statistically significantly increased from 53.07 to 54.61 after training ( $p<0.05$ ). Standing in GMFM statistically significantly increased from 94.47 to 95.85 after the intervention ( $p<0.05$ ). Gait, running and jumping in GMFM statistically significantly increased from 93.58 to 94.65 after the intervention ( $p<0.05$ ) (Table 2).

## DISCUSSION

Compared to normal children, even children with spastic cerebral palsy with a high functional level show leg muscle weakening<sup>7, 17</sup>). Geoffrey et al.<sup>18</sup>) stated that the ankle plantar flexors are the weakest muscles. Horvat<sup>9</sup>) reported that muscle strength in the paretic knee extensors and flexors was 42–52% of that on the unaffected side in hemiplegic children. Muscle-strength-enhancement training is critical for functional improvement in children with spastic hemiplegia<sup>4</sup>). Hence, this study examined the effects of concentric and eccentric exercise control training on the paretic leg in children with spastic hemiplegia.

Damiano and Abel<sup>4</sup>) reported that gross motor function and pediatric balance ability improved after leg-muscle-strength-enhancement training. Dodd et al.<sup>19</sup>) reported that GMFM, gait velocity, and walking upstairs improved in children with spastic diplegia after muscle-strength-enhancement training. Dodd et al.<sup>19</sup>) applied muscle-strength-enhancement exercises to ankle plantar flexors and knee extensors in children with spastic diplegic cerebral palsy and reported improvement in items D and E in GMFM. In this study, control training of the paretic leg resulted in significant improvement in GMFM, similar to previous literature reports.

Shumway-Cook et al.<sup>20</sup>) applied 5 days of intensive balance training in children with spastic hemiplegia and diplegia and reported significantly improved core stability. In this study, control training of the paretic leg caused significant improvement in balance ability in children. It is possible that control function and balance reaction improved due to stable muscle activity

**Table 1.** Characteristics of study participants

	Experimental group (n=15)	Control group (n=15)
Gender		
Male	9 (60.0) <sup>a</sup>	10 (66.7)
Female	6 (40.0)	5 (33.3)
GMFCS (L1/L2) <sup>c</sup>	11 (73.3)/4 (26.7)	12 (80.0)/3 (20.0)
Age (yr)	11.6 ± 2.0 <sup>b</sup>	60.1 ± 12.3
Height (cm)	123.1 ± 14.0	166.8 ± 10.0
Weight (kg)	28.3 ± 7.6	65.7 ± 8.8

<sup>a</sup>n(%), <sup>b</sup>Mean ± standard deviation; <sup>c</sup>GMFCS: Gross Motor Function Classification System

**Table 2.** A comparison of balance and Gross Motor Function before and after training

		Experimental group (n=15)	Control group (n=15)
Balance (score)	Pre-test	53.1 ± 3.1 <sup>a</sup>	52.1 ± 2.5
	Post-test	54.6 ± 1.4*	52.4 ± 2.4
Standing (score)	Pre-test	94.5 ± 3.1	92.9 ± 2.4
	Post-test	95.9 ± 2.5*	93.3 ± 2.9
Walking, running and jumping (score)	Pre-test	93.6 ± 4.3	91.1 ± 3.6
	Post-test	94.7 ± 3.9*	91.3 ± 3.7

<sup>a</sup>Mean ± standard deviation. \*p<0.05

of the hip, knee, and ankle joints through consistent full weight-bearing control in the paretic leg.

There are several limitations in this study. First, the sample size was small, and it is difficult to generalize the study results to all children with spastic hemiplegia. Second, because there is limited literature on weight-bearing muscle-strength-enhancement exercise in children with GMFCS level I–II, it was difficult to compare study results. Hence, research using a larger sample of children with spastic hemiplegia will be needed to determine the long-term effects of muscle strengthening on the paretic lower limb. Moreover, multidimensional analysis using appropriate assessment tools will be needed to validate the results of concentric and eccentric weight-bearing exercise.

Concentric and eccentric control exercise therapy in children with spastic hemiplegia can be used as a means to solve functional problems in a paretic leg.

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